The Importance of Belowground Plant Allocation for Terrestrial Carbon Sequestration and Climate Feedbacks

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RESEARCH OBJECTIVES

Soil organic matter (SOM) plays a central role in the carbon (C) cycle, by sequestering atmospheric carbon and by forming a feedback to climate change. The long turnover time of SOM compared to most plant tissues means that soils are a more efficient storage pool for C (i.e., more sequestration per unit net primary productivity [NPP]), with less interannual variability or disturbance-driven losses. We are conducting research to fill critical gaps in understanding of belowground carbon cycling in temperate forests, by quantifying:

- The lifetime of fine roots and its effect on belowground NPP
- Decomposition of root versus needles/leaves
- Total residence time of belowground C, including SOM
- Resource constraints on plant allocation

APPROACH

When plants allocate C belowground, the C cascades through several reservoirs—live roots, dead roots, microbial biomass, and humic organic matter—each with their own residence time and respiratory losses (Figure 1). A longer residence time results in more storage per unit C input. To predict C sequestration or the potential for ecosystem feedbacks to climate change, we need to understand the turnover times of C in each soil carbon pool, the pathways of C movement among pools, and the potential feedbacks to productivity.

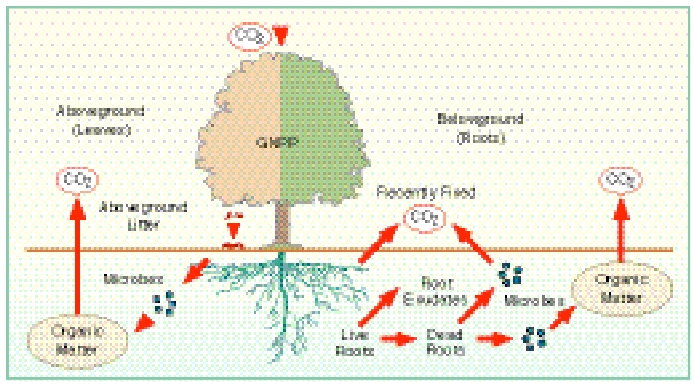
Accordingly, we have conducted field isotope-based experiments, including (1) natural abundance ^{14}C, to determine fine-root lifetimes; (2) litterbags and *in situ* incubations of ^{13}C-labeled litter, to estimate litter decay rates; and (3) ^{13}C-labeled litter, to track root and needle decay into soil-respired CO_2, microbial biomass, and soil organic fractions. The accomplishments represent work in ponderosa pine, mixed conifer-deciduous hardwood, and Norway spruce forests.

ACCOMPLISHMENTS

We find that fine roots live 2–5 years, longer than the historical assumption of annual turnover. The main implication of longer root life spans is that belowground NPP currently may be overestimated. We have begun modeling to produce better estimates of root turnover and NPP allocation. For decomposition, our experiments provide multiple lines of evidence that roots decay more slowly than needles or leaves, and there are differences in the microbial communities mediating decomposition of the tissues. For SOM, we have documented the importance of depth and mineralogy in long-term carbon storage. We have published eight peer-reviewed articles, presented at a dozen venues, and supported two post docs, one Ph.D. student, and more than 10 undergraduates.

SIGNIFICANCE OF FINDINGS

Our results to date imply that the same amount of primary productivity leads to more C storage if it is allocated to fine roots rather than to leaves or needles in these temperate forests. Translating these results to a sequestration strategy or analysis of feedbacks poses challenges that we are addressing in the second phase of our research. It appears from our early results that plant allocation patterns influence the plant's ability to acquire and use belowground and aboveground resources, which may in turn feed back to shape productivity and long-term C sequestration.



RELATED PUBLICATIONS

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Mikutta, R. M. Kleber, M.S. Torn, and R. Jahn, Stabilization of soil organic matter: Association with minerals or chemical recalcitrance? Soil Science Society of America Journal (in press), 2005.

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